

AIRBORNE LIDAR SURFACE TOPOGRAPHY (LIST) SIMULATOR

*Anthony W. Yu, Michael A. Krainak, David J. Harding, James B. Abshire, Xiaoli Sun,
John Cavanaugh, Susan Valett, Luis Ramos-Izquierdo, Tom Winkert, Michael Plants,
Timothy Filemyr, Brian Kamamia, William Hasselbrack*
NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA

1. INTRODUCTION

In this paper we will discuss our development effort of an airborne instrument as a pathfinder for the Lidar Surface Technology (LIST) mission. This paper will discuss the system approach, enabling technologies, instrument concept and performance of the Airborne LIST Simulator (A-LISTS).

2. OBJECTIVES

At NASA GSFC, we are developing technologies for a next-generation, efficient, swath mapping, space altimeter for Earth science. Our approach allows simultaneous measurements of 5-m spatial resolution topography and vegetation vertical structure with decimeter vertical precision in an elevation-imaging swath several km wide from a 400 km altitude Earth orbit. This capability meets the goals of the LIST mission recommended in the Earth Science Decadal Survey by the NRC Committee on Earth Science and Applications from Space.[1] Such swath mapping elevation measurements meet many Earth science needs, including (1) mapping topographic changes associated with natural hazards; (2) global surveys of vegetation height and biomass, and their response to disturbances; (3) measurements of river and lake levels for monitoring water storage and discharge changes in the global water cycle; and (4) long duration satellite observations of ice sheet and glacier mass balance from measurements of their elevation change. The approach can also be scaled and used with less laser power and smaller telescopes for mapping planetary surfaces for science and exploration. In 2007 we began work on an Instrument Incubator Program (IIP) to advance and demonstrate needed technologies for the LIST mission with the A-LISTS pathfinder instrument. A-LISTS is a micropulse, photon-sensitive waveform recording system that is based on a new, highly efficient laser measurement approach utilizing emerging laser transmitter and detector technologies.

3. A-LISTS INSTRUMENT

The A-LISTS instrument uses a single laser to generate sixteen beams for high-resolution mapping. Backscatter from the surface is collected with a telescope and the spots from the swath are imaged onto a photon sensitive detector array. The output from each detector element is histogrammed and analyzed to determine ranges to the surface and derive echo waveforms that characterize the vertical structure of the surface. This signal processing

technique allows for through-foliage interrogation in order to observe the ground surface beneath vegetation cover and to characterize vegetation vertical structure. The most challenging measurement goal for LIST is detection of the ground surface beneath vegetation cover with 98% closure at 5 m spatial resolution. The measurement approach we will demonstrate with A-LISTS is designed to meet that requirement.

The laser is based on a high repetition rate Yb:YAG microchip laser [2] with a Cr^{4+} :YAG saturable absorber and a volume Bragg grating as output coupler for wavelength stabilization. The output energy of the microchip laser is $\sim 100 \mu\text{J}$ at 2 kHz with a 960 ps pulse width. The spectral width of the laser is measured to be $\sim 13 \text{ pm}$. This single laser beam is then divided into sixteen beams using a pair of microlens arrays (MLA) [3] and oriented in a 4x4 grid pattern. Each of the sixteen beams has a divergence of 0.5 mrad with center-to-center beam separation of 2 mrad. At 10 km altitude, the individual beam spot on the ground will be approximately 5 m. The 4x4 grid pattern is clocked at an angle relative to the aircraft flight direction so that during flight, it forms a swath width of approximately 80 m from 10 km altitude composed of 16 parallel, adjacent profiles. The grid pattern provides contiguous coverage with the advantage of minimizing spatial crosstalk on the detector array. In A-LISTS the laser will operate at 2 kHz yielding a laser footprint along each beam profile every 9 cm at the nominal aircraft altitude of 180 m/sec. This is over-sampled by $\sim 8\times$ as compared to our spaceflight LIST concept utilizing a 10 kHz laser at a velocity of 7 km/sec.

The returned signal from the ground is captured by a 20 cm diameter ruggedized, athermal telescope. The image of the 4x4 ground pattern is captured by a 4x4 fiber bundle and routed to a 16-element photon-sensitive detector array. The detector is an InGaAsP intensified photodiode detector (IPD) array. The IPD contains a 4x4 anode array of photon sensitive avalanche diode anodes. The expected quantum efficiency at 1030 nm is $>20\%$ at $1 \mu\text{m}$ wavelength, dark count of $<0.5 \text{ MCounts/second/pixel}$ and gain of $>10,000$. [4] The output of this array will be sent to a 16-channel, 1.5 GSamples/s, 8-bit digitizer to record an echo pulse waveform. The detection rate will be controlled to be a few 10 's of photons per laser fire per beam by attenuation of the outgoing pulse energy in order to emulate the expected rate of our LIST measurement concept. This approach has the advantage of single photon receiver sensitivity but multiple photon dynamic range and no detector dead-time.

Using a range window of $10 \mu\text{s}$ (or 1.5 km) the expected raw data rate is 480 MB/s for all 16 channels that will be stored using commercial off the shelf equipment. In post processing, the waveform output from multiple laser fires along a profile will be aggregated at 5 m spatial scale to yield a composite waveform used for ground detection and canopy structure characterization. The over-sampling along profiles will be used to conduct sensitivity studies to guide refinement of our LIST mission measurement approach.

Engineering flights of this instrument are scheduled for April 2011; we will be demonstrating the performance of the A-LISTS instrument by acquiring data over a variety of topographic and land cover conditions. A focus will be demonstration of the ground detection through dense, closed-canopy forest cover. The component

technologies, algorithms and measurement approach developed under the IIP effort will provide a path forward to the capabilities needed to meet the challenging requirements of the LIST mission

4. ACKNOWLEDGEMENT

We gratefully acknowledge the support from NASA's Earth Science Technology Office (ESTO).

5. REFERENCES

- [1] *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond*, National Research Council of the National academies, The National Academies Pres, Washington D.C., (2007).
- [2] E.P. Ostby, et.al., *Proc. SPIE*, vol. 5707, pp. 72-80, 2005.
- [3] Krainak, M., patent disclosure, case GSC15,520-1, "Imaging Device."
- [4] X. Sun, et.al., *Proc. SPIE*, 6583, p. 65830D, 2007.